# AESTHETIC LIGHTING DESIGN ON INCHEON BRIDGE

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## *Abstract*

*The lighting of Incheon Bridge, a maritime cable-stayed bridge, is a major nightscape element intended to emphasize the landmark symbolism of Incheon City. Lighting on cables and main towers that are architectural characteristics of the cable-stayed bridge have been designed in consideration of various distant viewpoints, maritime weather conditions, and geographical conditions neighboring Incheon International Airport. Those tasks, including the restriction of upward light leakage and glare facing drivers as revealed through a demonstration of the process of design review have been resolved through diversified technical reviews and testing. Upward light leakage has been minimized by selecting alternative lighting fixtures in consideration of luminance distribution characteristics and lighting efficiency. Designing a special louver and lighting poles was decided on to exclude possible obstructions to safe driving through a structural review. With color lighting playing a key role in lighting presentation, convenience of operation and future maintenance have been considered by attaching a full automatic color changer in front of the normal flood lights.*

FIGURE 1 – Incheon Bridge (Day, Night-Maritime, Night-Road)

## BRIDGE LIGHTING OVERVIEW

City lighting is part of the cityscape and has a presentation effect for urban areas. Lighting upward using flood lighting on historical buildings or bridges or lighting on roads, plazas, parks, etc. has been executed across cities in various countries in the world, so that even things not obvious in the day become city landmarks at night and symbols of history or individuality.

Bridge lighting signifies the culture and age of the region the bridge is located, and completeness of lighting is highly evaluated when formative beauty and functionality contained in the bridge are presented without interference. From this point of view, the lighting of Incheon Bridge will make it a beauty spot of Incheon City when it is reborn as an expression of identity and a formative visual object of Incheon City, all part of the sightseeing resource plan in the Incheon Free Economic Zone.

FIGURE 2 – Bridge Lighting in the city (Akashi-Japan, Harbour Bridge-Australia, Golden Gate Bridge-USA)

## DOMESTIC CABLE-STAYED BRIDGE LIGHTING EXAMPLES

| Name of Bridge | Overview | | Construction Cost (100 Mil. Won) | Construction Period | Main Tower Lighting | Cable Lighting | Presentation | Image |
|---|---|---|---|---|---|---|---|---|
| | No. of Lanes (Bridge Width) | Length of Cable-stayed Bridge (m) | | | | | | |
| Incheon Bridge | 6 | 1,480 | 16,000 | '05.06-'09.10 | LED Lighting, Exterior-Interior Color Lighting | Flood Lighting in Cable Direction (216 ea) | Seasonal Color Change (Main Tower) |  |
| Seohae Bridge | 6 | 990 | 6,052 | '93.11-'00.12 | Top/Bottom Color Flood Lighting | Flood Lighting in Cable Direction: 12m Interval (60 ea) | Seasonal Color Change |  |
| Machang Bridge | 4 | 740 | 2,648 | '04.04-'08.06 | Horizontal Beam LED Lighting, Exterior-Interior Color Flood Lighting | Flood Lighting in Vertical Direction of Cable: 25m Interval (32 ea) | Seasonal Color Change |  |
| Samcheonpo Bridge | 2 (14.5m) | 436 | 1,650 | '95.02-'03.04 | Top color Flood Lighting, Bottom White Flood Lighting | Flood Lighting in Cable Direction | Seasonal Color Change |  |

TABLE 1 – Comparison of Domestic Cable-stayed Bridge Lighting Examples

## LIGHTING DESIGN PROCESS

| Analysis | >> | Basic Design | >> | Approval | >> | Test | >> | Detailed Design | >> | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|
| Environment Analysis<br>Bridge Drawing Review<br>Related Law Analysis<br>Owner's Opinion | | Concept<br>Specialization Plan<br>Lighting Presentation Plan | | Samsung<br>Korea Highway Corp.<br>Ministry of Land, Transport & Maritime Affairs<br>IFEZ<br>Seoul Regional Aviation Administration<br>Maritime Affairs & Port Office | | 1st (Cable)<br>2nd (Color Lighting)<br>3rd (Lighting Fixture) | | Piping and Cabling<br>Lighting Control<br>Structure Review | | Maintenance Manual<br>Integrated Management System<br>Expected Cost Calculation |

TABLE 2 – Lighting Design Process of Incheon Bridge

## OBJECTIVES OF LIGHTING DESIGN

- To emphasize the beauty of the structural shape of Incheon Bridge
  - To configure a harmonized luminance and color contrast of the main tower/cable/bridge sides/piers

- To present various changes upon season/ordinary days/weekend/events
  - To increase tourism effects by generating expectation and curiosity among tourists by changing presentations over a time span.

- Appropriate harmonization with the ambient environment
  - To consider the prospects of Wolmido, Youngjongdo, and Songdo and luminance contrast with the background of the sky and the sea.

- To consider the convenience of maintenance and management and to use efficient fixtures
  - To select salt resistant material, painting treatment, and efficient lighting fixtures

- To reflect structural or mechanical stability against sea water/sea winds (typhoons)
  - To install blocks at appropriate heights and use drainage and lighting fixtures with IP 65 or higher

## BASIC LIGHTING DESIGN

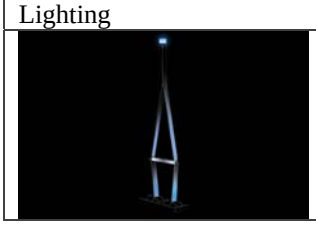
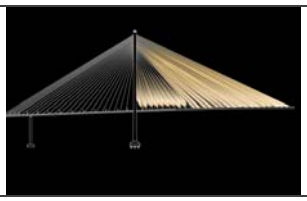
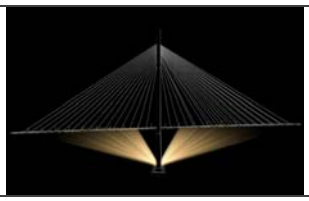
| Cable-stayed Bridge | | | Approach Bridge |
|---|---|---|---|
| Main Tower | Cable | Bridge | Pier |
| Peak – LED Lighting | Cable - White Flood Lighting | Rear Side - White Flood Lighting | Pier – White Flood Lighting |
| Interior/Exterior – Color Flood Lighting | | | |
| Girder – White Flood Lighting | | | |
|  |  |  |  |

TABLE 3 – Types of Lighting for Parts of the Bridges

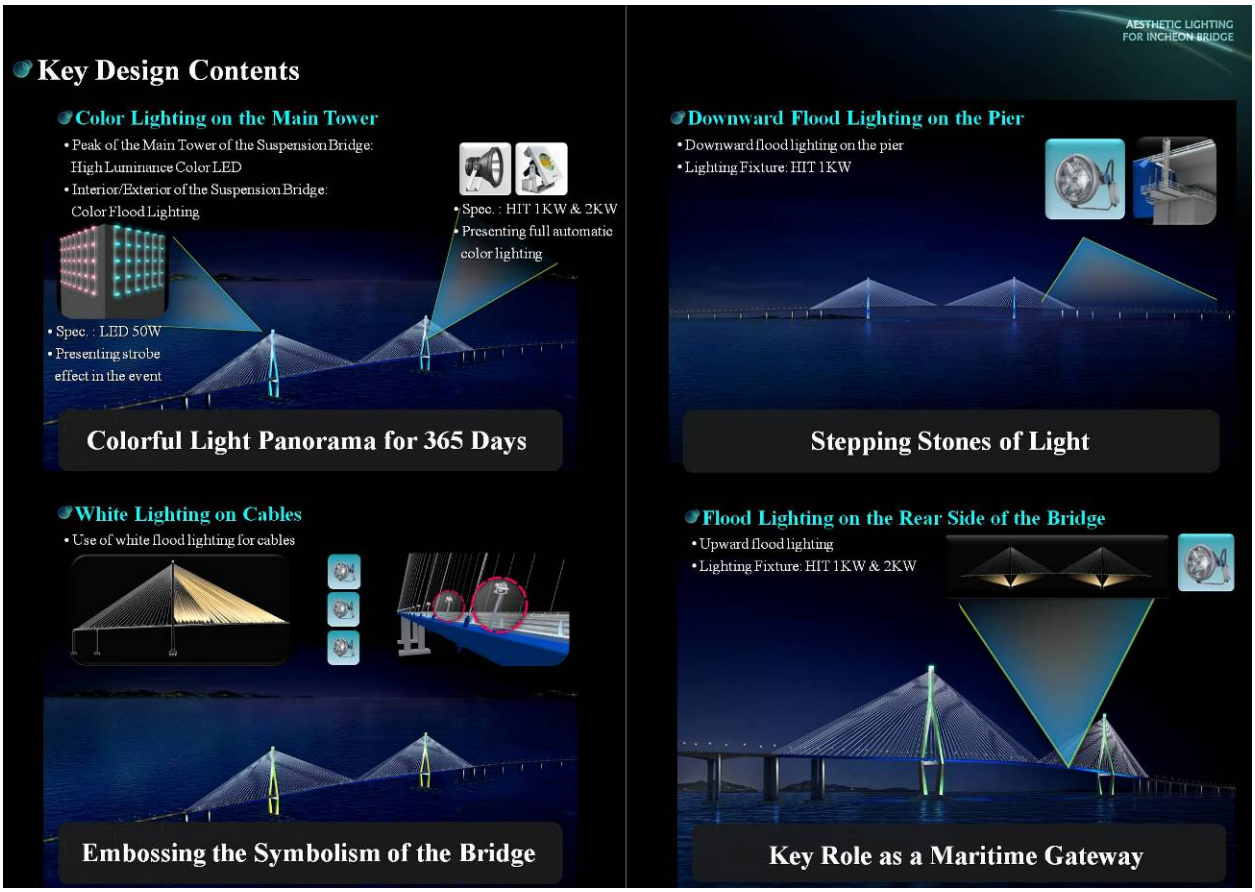



FIGURE 3 – Key Design Features

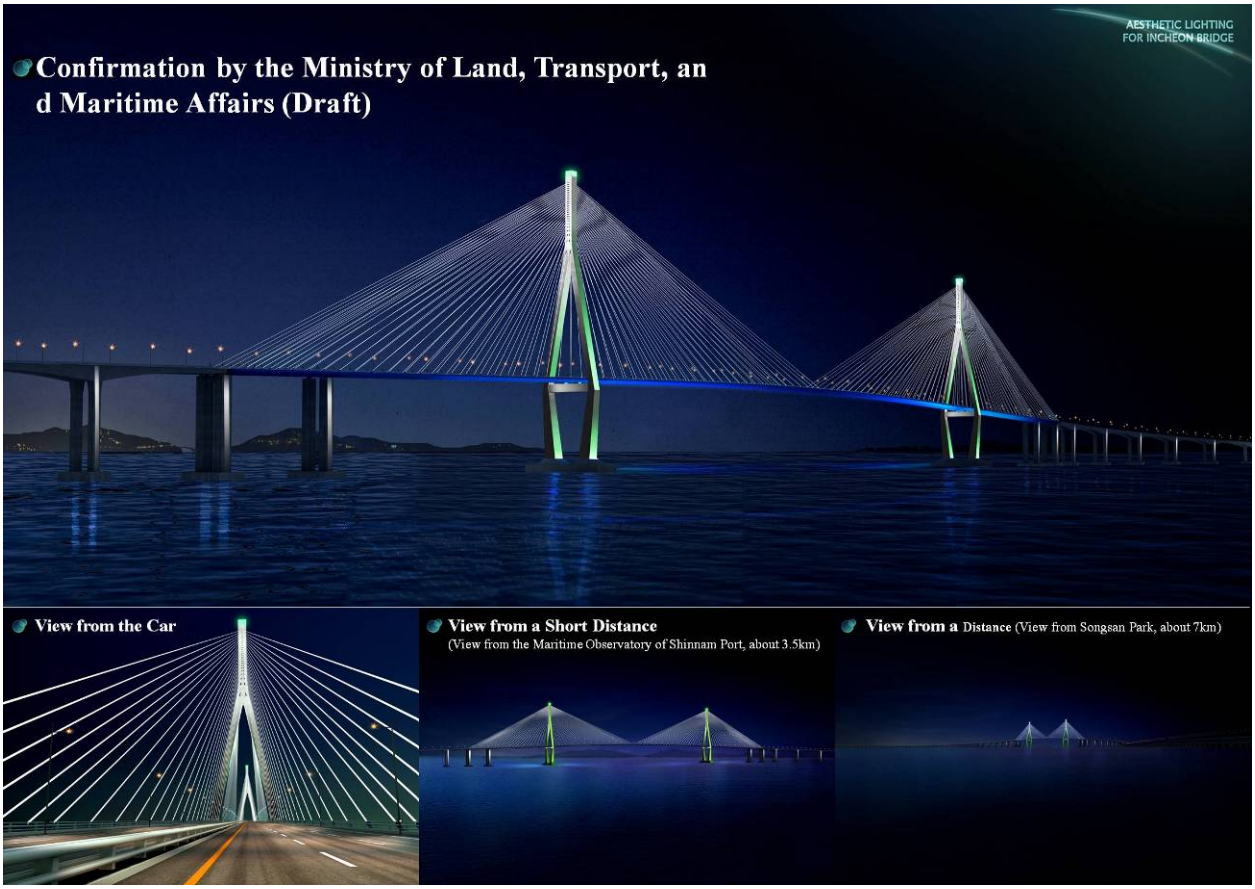



FIGURE 4 – Computer Simulation Images for each View Point

## LIGHTING ONTO THE CABLES (Review of White Lighting onto the Cables)

- **Existing Method 1 (Upward Flood Lighting on the Exterior of the Cables)**

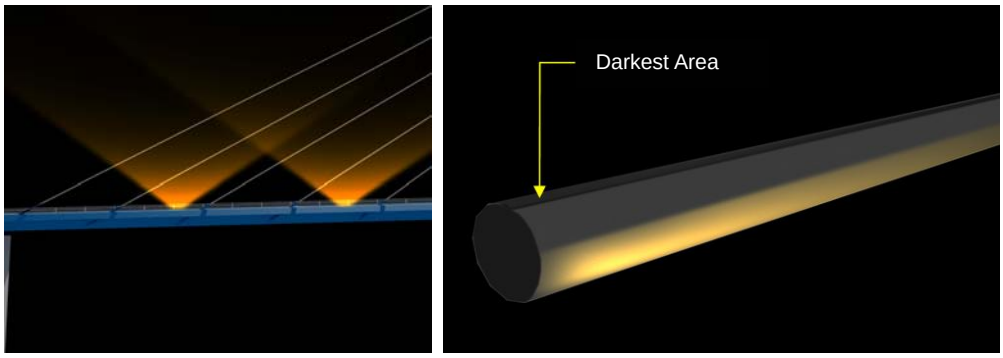



FIGURE 5 – Upward Flood Lighting on the Exterior of the Cables

This is flood lighting from the bottom to the top of a number of cables with a small number of lighting fixtures with Flood-up Light, which is advantageous for those bridges that are not high. It does have some disadvantages as it requires additional lighting for the main tower and the dark shapes of cables do form from the road view. In addition, due to visual phenomenon, as the highest luminance surface is the lower exterior of the cables, the cables can look shorter and smaller.

- **Existing Method 2 (Flood Lighting Aiming at the Exterior of the Cables)**

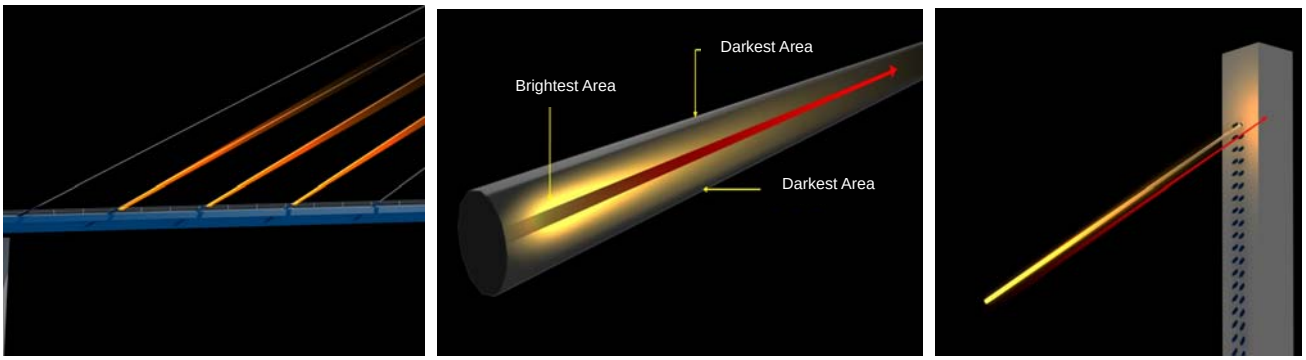



FIGURE 6 – Flood Lighting Aiming at the Exterior of the Cables

This is a method used to project light focused on each cable toward the main tower with a Spot Light. It allows for the central areas of cable exteriors to be mainly bright, but has the disadvantage of using only part of the flood lighting distribution. The inner sides of the cables can appear relatively dark from the road. Accordingly, as the brightness of the bright central area is mostly detected, the cables can look relatively thin.

| 1 (Existing Method) | 2 (Existing Method) | **3 (Adopted Method)** |
|---|---|---|
| Upward flood lighting on the exterior of the cables | Aiming flood lighting to the exterior of the cables | Aiming flood lighting to the interior/ exterior of the cables |
| Example: Machang Bridge<br>Features: Low use rate of lighting<br>Uneven luminosity according to view points | Example: Seohae Bridge<br>Features: Low use rate of lighting<br>Dark luminosity of cables from road view points. | Example: Incheon Bridge<br>Features: High use rate of lighting<br>Constant luminosity is kept according to view points |

TABLE 4 – Comparison of Cable Flood Lighting Methods

- **Adopted Method (Flood Lighting Aiming at the Interior/Exterior of the Cables)**

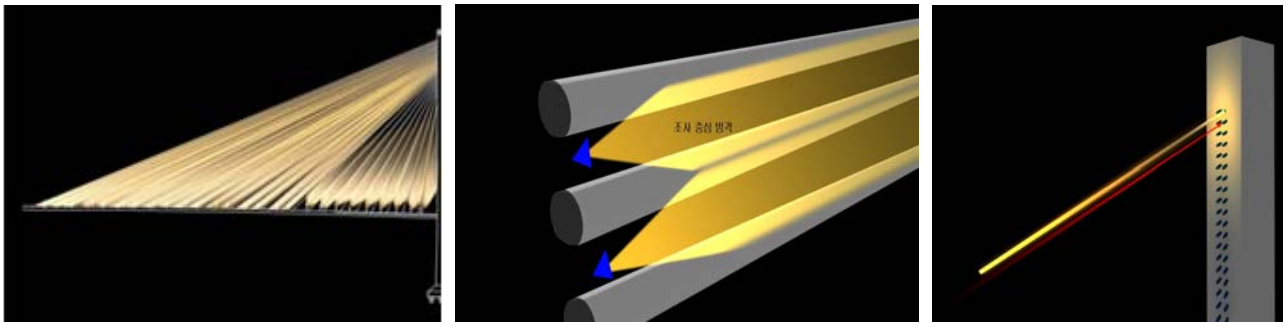


FIGURE 7 – Flood Lighting Aiming at the Interior/Exterior of the Cables

It has been successfully applied to foreign cable-stayed bridges and is effective in increasing the brightness the cables. It is a method intended to place flood lights between cables, a half portion of which touches up both upper/lower cables.

A roughly 360° circumference of the cable gets light, and the darkest black zone appears as a long line at the center of the cable. However, even though this black zone is expected to be shown from the straight line at the opposite of the bridge, it is a prerequisite that we must see the bridge from any angle and we can barely see the black zone from the opposite straight line.

Consequently, the cables appear thick, as their surfaces expand at the maximum diameter, becoming the brightest spots with the high utilization of light to use a 70-80% luminance distribution.

As the light is evenly radiated on the interior and exterior of the cables and almost of all remaining light on 6m width of the peak of the main tower, the area where cables are gathered becomes brighter.

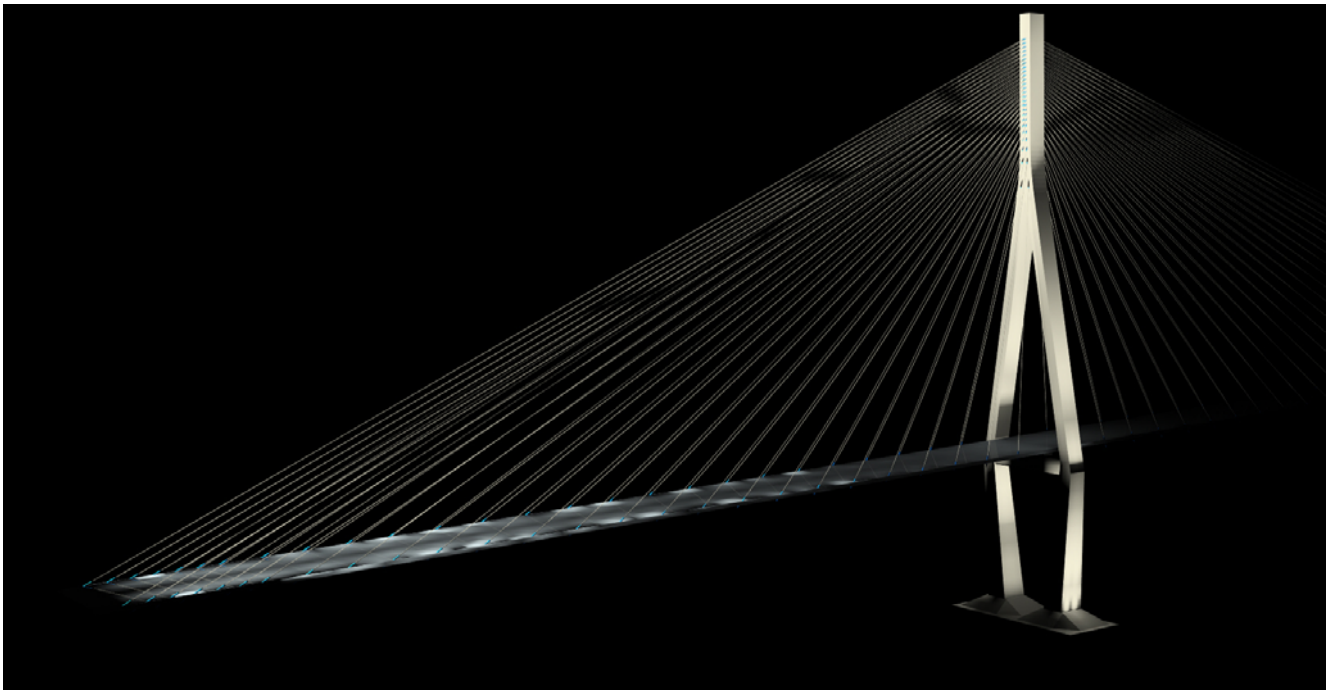


FIGURE 8 – Computer Simulation of Flood Lighting Aiming at the Interior/Exterior of the Cables – LIGHTSCAPE 3.2

## COLOR LIGHTING ON THE PYLON (Review of Color Flood Lighting on the Main Tower)

High-capacity color floodlights are divided into three types according to the filter use methods.

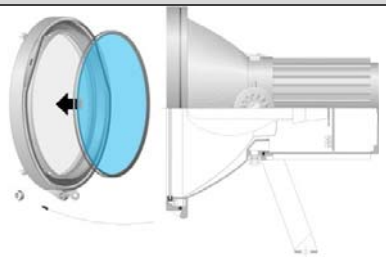
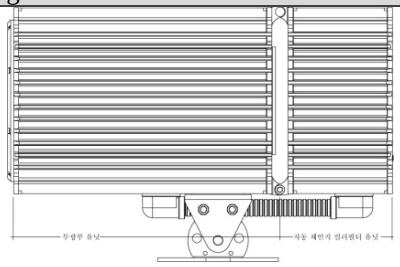
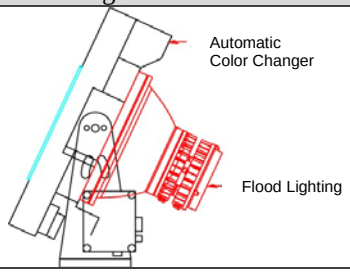
| 1 (Existing Method) | 2 (Existing Method) | **3 (Adopted Method)** |
|---|---|---|
| An analog method designed to attach R, G, B, W filters to the lighting fixture to mix colors | A digital method designed to interoperate R, G, B filters inside one light fixture | A digital method designed to attach a color filter digital set on the front side of the floodlight |
|  |  |  |

TABLE 5 – Comparison of Color Lighting Methods

Method No. 1) is a traditional analog method comprising one set of four lighting fixtures. In order to mix colors, two or more lights should be turned on in addition to the basic color.
(R+G+B, R+G, R+B, G+B, W 5 colors available)

Method No. 2) uses a fixture modified with a stage lighting fixture for outdoor use. The driving device is digitalized. However, as it does not have diverse capacities, giving it a number of restrictions in terms of lighting plans with some fixtures, it is commonly used for special effects. Lamps are also mostly special lamps with short lifespans of which the 700W grade is the largest capacity due to the closed space. 1KW or higher grade cannot guarantee endurance due to the air cooling structure allowing the permeation of sea water.

Method No. 3) has a number of advantages to attach digital controlled color filter sets used in front of normal floodlighting. As it can be used for all floodlights, it is possible to ensure a diverse range of presentations with a low initial investment, uses a lower number of fixtures, (with one filter set for one fixture), than Method No. 1), and uses cheaper filter equipment than that of Method No. 2). In addition, as it can utilize the lifespan of lamp to the maximum, (normal metal halide lamp), it reduces maintenance costs and ensures easy management with a digital remote control program.

## ON-SITE LIGHTING TEST AND DEMONSTRATION

In order to review and complement the detailed design on the basis of the basic design, three demonstrations were conducted to which relevant persons were invited and discussions held afterwards.

Through the demonstrations, in the case of floodlighting for the cables, the use of alternative lighting fixtures with narrow angles and special louvers to minimize unnecessary surplus light were reflected in the detailed design.

In addition, for a fundamental solution to the glare phenomenon that may impact on safe driving, exposure on the direct light source or direct louver reflection highlight has been resolved by proposing a method of installing lighting fixtures on the lighting poles in order to place the installation position of the lighting fixtures on higher positions than the driver line of sight.

The louver to be installed at the front side of the cable floodlighting has been modified and complemented through several tests, to ensure that it can maintain the lighting efficiency of the lighting fixtures as much as possible, while effectively blocking any unwanted spreading of light from the high luminance lighting fixtures.

In the case of color floodlighting, it was concluded that the anticipated brightness recognized from distant viewpoints is lower than the white floodlighting for the cables. The reason is that transmissivity of the automatic color changer was set to a low level during the implementation of the proper contrast for the four basic colors adopted during the basic design. Therefore, brightness reinforcement has been attempted through a capacity extension of the color floodlighting.

| | 1st Demonstration | 2nd Demonstration | 3rd Demonstration |
|---|---|---|---|
| Contents | 1. White floodlighting for the cables<br>2. Color floodlighting for the main towers | 1. Flood lighting for the cables (alternative lighting fixture)<br>2. Color floodlighting for the main towers (capacity increase)<br>3. Bridge side LED<br>4. Installation of glare restriction hoods | 1. Lighting pole<br>2. Lighting fixture louver |
| Results | 1. Confirm the visual effect of cable floodlighting<br>2. Need to change the lighting fixture raised to the minimize upward light leakage levels<br>3. Driver glare restriction hoods<br>4. Need to reinforce color lighting | 1. Need to adjust upward light leakage raised<br>2. Need to install a pole that is a fundamental method for restricting glare for drivers<br>3. Confirm the visual effect of color lighting | 1. Confirm the visual effect of pole Installation (To restrict driver glare)<br>2. Confirm the visual effect of special louver (To restrict upward light leakage) |

TABLE 6 – Contents and Results of Demonstrations

## POLE DESIGN FOR CABLE LIGHTING

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pole Design | >> | Pole Structure Design | >> | Pole Base Design | >> | Wind Tunnel Test | >> | Vibration Test | >> | Finish Color |

TABLE 7 – Lighting Pole Design Process of Incheon Bridge

One cable floodlight is placed on the straight line of the cable, between cables. The radiating angle of the projection lamp is a method designed to increase efficiency at parallel positions with the cable, and is an important component of the entire aesthetic presentation plan.

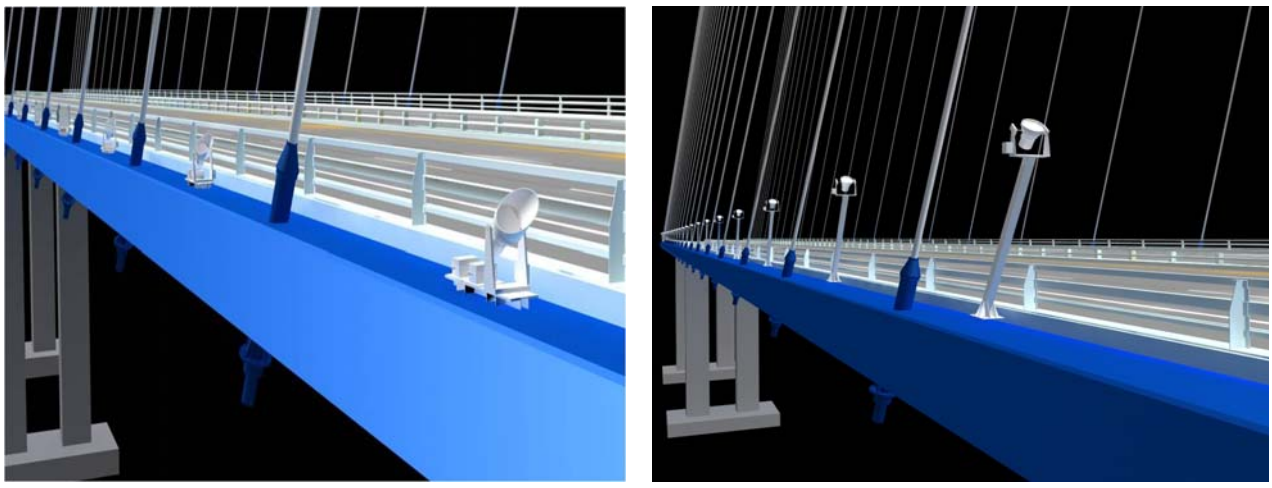


FIGURE 9 – Anticipated Images Before/After the Installation of Cable Lighting Poles

However, what is more important than the aesthetic aspect is the function as a road, which may be hampered if there are visual problems when driving. It has been concluded that the need to adopt a lighting fixture pole is inevitable as a fundamental solution of visual environment problems for drivers. This was found during two separate demonstrations.

As pole design is a very important factor for daytime environments, its exterior should be designed as a refined fixture harmonized with the ambient structures. The appropriate height to block driver glare, etc. has been reviewed and reflected in the pole design. In addition, considering that it is installed on the cable-stayed bridge, a structure review has been performed through diverse pole structure calculations and wind tunnel testing.

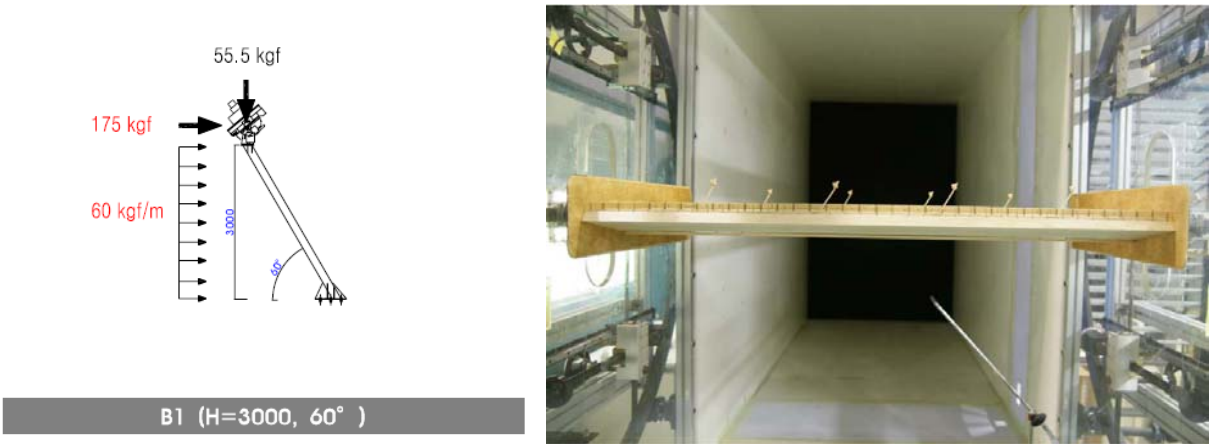



FIGURE 10 – Pole Structure Calculation and Wind Tunnel Test

## INTERGRATED LIGHTING CONTROL

Lighting controls can be divided into lighting schedule control and lighting presentation control. Different from street lights operating between sunset - sunrise, aesthetic lighting is generally operated for 4-6 hours between sunset and midnight, when night activities are generally active, and is partially or completely turned off between midnight and sunrise. In addition, during specified anniversaries or events, the lighting schedule will be adjusted through discussions with the main body operating the lighting.

Lighting presentation control can be performed through controls of the brightness, colors, and number of lighting components. It is classified by time and season based on the presentation plan proposed on the basic lighting plan, and an Integrated Lighting Control System has been implemented on the TOLL PLAZA where the basic lighting presentation may be revised or complemented in real time.

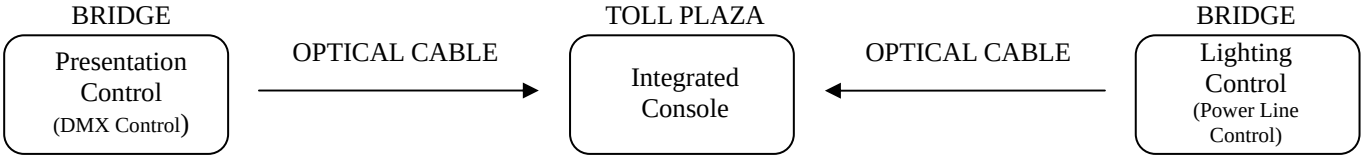



FIGURE 11 – Lighting Control Concept Diagram for Incheon Bridge

## CONCLUSION

Lighting on Incheon Bridge, a maritime cable-stayed bridge, is a key element of the nightscape for Incheon City. For the lighting on Incheon Bridge, which has been planned and designed on the basis of geographical, technical, and social requirements, diverse technical reviews and tests have been conducted in order to resolve the problems encountered, such as the restriction of upward light leakage and driver glare, as revealed through demonstrations.

Floodlighting for relatively thin cables compared to the scale of the bridge has become a significant task. Considering the viewing characteristics of Incheon Bridge, allowing views from all directions 360°, aiming floodlighting to the interior/exterior of the cables in order to complement the existing cable floodlighting, a commonly used practice in Korea, has been adopted. Special louvers able to solve the problem of surplus light and the unique characteristics of high luminance floodlighting fixtures that retain lighting efficiency have been manufactured. It has been designed so that all unnecessary surplus light is absorbed through a low reflective surface if the louver and luminous intensity at the center of the lighting fixture can be maintained, and so that as much light as possible reaches the cables.

Due to the characteristics of aiming floodlighting to the interior/exterior of the cables, lighting fixtures are placed aiming at the cables in parallel. This resulted in the problem of exposing light sources with high brightness levels directly at drivers, affecting visibility levels. As it was impossible to find a fundamental solution through modifications or complementing the special louver as mentioned above, a lighting pole has been introduced in order to place lighting fixtures higher than the line of sight of drivers. At the detailed design stage, its effects on the cable-stayed bridge and lighting fixtures due to vibration through a phased structure review were analyzed and reflected in the design.

For the color lighting, removable full automatic color changers that allow for the advantages of manual replacement methods and integrated lighting fixture types where necessary for the filters were used, as is common throughout Korea. The color changers have the advantages of long lifespan metal halide lamps, and the automatic control of color presentation provides convenience of operation and maintenance.

## REFERENCES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[2] Yoonseok Choi, Inyoung Jeong, Hyuntae Ahn, Jeongtai Kim, 2006, “Analysis of Luminance Distribution of Illuminated Bridges by View”, *Journal of KIIEE*, Vol. 20, No. 6, 1-8.